Let x, in a system of rectangular coördinates, represent mass, and y absolute temperature, then the area, xy, will be proportional to the energy, or, with a suitable unit of temperature, will equal it. Now, we may cut this area into n equal parts by vertical lines, which will also cut the mass into n equal parts. In such case it requires no scientific imagination to see that these parts are similar and 'similarly circumstanced;' but this is altogether too simple for the use to be made of it, and no such statement can pass for a law of thermodynamics; it is simply the law of homogeneousness.

Rankine leads up to his statement in an unfortunate way, perhaps, emphasizing the fact that every particle is equally hot. Well, so it must be, or the upper line of the figure would not exist, or would be curved, which would interfere with the argument, because there would then be no one temperature for all the molecules. But Rankine intended no such vertical subdivision: in fact, he says, 'Let unity of weight,' etc.; and we may take a differential unit, and so put such a division out of the question. The division intended by Rankine was by horizontal lines, which makes the statement of the law identical with the other: only he says here, 'heat;' and there, 'temperature;' and he commences with heat, because heat is energy, and changes to temperature, because temperature is the practical way of estimating this energy, and is proportional to it.

We believe, then, that this is the one and only second law; and as our agent is a quantity of energy, and as energy resides in mass, whereas different substances do not differ in their mass, therefore the particular working substance used has no effect.

We will now look again at the formula for efficiency, which flows directly from Rankine's law, in a simple and evident manner.

If we could make an infinite-cylinder engine, this formula would not be needed. This engine works *at* a temperature, not *between* two temperatures, and it transforms all the heat into work. But mechanical considerations require us to build engines that run in cycles, and we then need it. Every engine running in a cycle is a double engine, consisting of an engine proper and a condenser; i.e., while the piston rises in the cylinder, which we cannot make infinitely high, we transform heat into work completely: then we must use our engine as a condenser for recompressing the gas; and, while doing so, we transform work completely into heat; and if we lower the temperature of the gas before compressing it, there remains a margin of work, according to the efficiency formula.

It should be remarked, that we have made no special reference in this address to any thing but a perfect-gas engine; and we believe the theory of this should be made clear before introducing the necessary modifications to include liquids and solids: Rankine has, however, framed his formula to cover both. Many other points have been left untouched; but if I have made plainer how heat, and therefore temperature, may be supposed to consist of any number of equal parts, and convinced you that Rankine's is the real and only second law, my main object will have been accomplished.

PROCEEDINGS OF THE SECTION OF MECHANICAL SCIENCE.

THE valuable work done by a few in this section deserves the special recognition and support of all its members. The four divisions under which this work may be classified, embrace wide and interesting fields of thought and study. These divisions are, Technical education, Accurate standards of measurement, General, scientific and practical engineering work, and Original investigation. These are proper lines of work for the advancement of 'mechanical science and engineering,' because they include the education of men for the work; the production of instruments and appliances suited to the work; excite enthusiasm, and diffuse knowledge, among the workers; and enlarge the realm subjected to the exact knowledge and control of the intellect and will of man.

The first paper read before this section was on the strength of stay-bolts in boilers, and gave an account of experiments by the writer, Mr. L. S. Randolph. These experiments were designed to furnish data for the explanation of the peculiar manner in which the stay-bolts between the fire-box and boiler-shell had been found to break. The theory was, that the extreme difference of temperature liable to occur between the parallel plates — being at times 200° F., — caused a shifting of these plates, parallel to one another, sufficient to bend the stay-bolts considerably; and that this bending, occurring near the surface of the plate into which the bolt is screwed, caused the bolts to break at this point. The amount of such bending having been calculated from the known difference of temperature and the length of the plates, the experiments showed that if similar stay-bolts were subjected to this amount of bending, they would ultimately break, thus, apparently, confirming the theory. In the discussion, different forms of bolts or stays were suggested as likely to remedy the difficulty. The adoption of a link in place of a bolt was thought to be impracticable in this case on account of the small distance between the plates. Proportioning the stays so as to enable them to bend under the stress to which they are subjected without reaching the elastic limit of the material, was suggested as a remedy for the difficulty. It was shown that stays are sometimes worn away by being vibrated or bent. This bending causes the scale which has been formed to be thrown off; and oxidation occurring again under the action of the water, this new scale is thrown off, and this process continued wears away or 'channels' the iron.

A short abstract of a paper on a universal form of pressure-motor by Prof. D. P. Todd was presented by

the secretary. The abstract enumerated the advantages of the arrangement of multiple radial cylinders, the pistons of which act upon the inside of a vibrating eccentric. In the discussion, several novel forms of this kind of motor were recalled, as having been used or tried; but it was shown, that thus far the advantages claimed had not usually been sufficient to counteract the objection of complicated construction. Being best adapted for slow speeds, these motors are not economical for steam on account of excessive cylinder condensation.

The subject of the next paper, by Mr. Stephen S. Haight, was the use and value of accurate standards for surveyors' chains. The chain described was of flattened steel-wire, with thermometer attached to record temperature, a spring-balance to weigh the tension under which the chain is used, and a spirit-level. Professor Davis exhibited a tape, such as his experience had proved to be practical for ordinary work, and which, though not capable of so great accuracy, perhaps, as the one described by Mr. Haight, he had found amply so for general use in a large range of work in the state of Michigan. Professor Davis also exhibited a reel of simple construction. The president read some notes from Prof. W. A. Rogers, chairman of a committee on standards of measurement. These notes contained one suggestion relating to greater precision in the use of calipers. As shops are coming more into the practice of having tool-rooms, Professor Rogers proposes to have a comparator in the tool-room of each shop, and to have the calipers sent to this room to be nicely set to exact size, thus eliminating the errors so sure to exist under the ordinary methods. The fact, that some metals and alloys when subjected to change of temperature do not return to their original volume when the normal temperature is restored, was mentioned as a possible cause of variation in standard measures, and fault of adjustment in instruments of precision made of such metals. Iron does not show this property of a 'set' in the ordinary range of temperature within which such instruments are used. The committee on accurate standards was continued for another year.

A short paper by Prof. J. B. Webb, on the lathe as an instrument of precision, called attenion to the lack in most lathes of that exactness of construction required to give a lathe the 'fine sense' of precision which some instruments possess, so that it is usually a machine for the economic removal of metal, rather than for the production of exact forms. There is at present no uniform method or available apparatus by which a purchaser may test the degree of error in any given lathe. Some simple methods for making such tests were briefly described. Another paper by the same author, on the economy of accurate standards, set forth the increased money-value of such articles as machine-bolts, screws, etc., when nicely fitted by accurate standards.

A paper by Mr. C. J. H. Woodbury, on the coefficient of efflux of automatic sprinklers, described these sprinklers, which are devices for extinguishing fires. The sprinklers are attached to pipes, and the water is automatically let on to the sprinklers by the melting of solder under the action of heat caused by the fire. It often happens that the pipes conveying the water to the sprinklers are too small to deliver the required volume of water. The paper gave the results of the author's experiments for determining the coefficient of efflux, and the formula for discharge of automatic sprinklers attached to commercial fittings; also the means of determining the number of sprinklers on given pipes, which will make the losses due to friction approximately equal, and not so great as to impair the efficiency of the apparatus. In the discussion, various methods of preventing the freezing of the water in winter were described, a simple one being to fill the exposed pipes with compressed air. This involves careful fitting of joints and valve-stems. This has been done so successfully as to show a loss of only two pounds' pressure per week from leakage. Where an air-tight tank is used, the compressed air may fill the space above the water in the tank as well as the exposed pipes. In this case, there need be no valve or mechanism between the tank and the sprinkler; and when the passage to the sprinkler is automatically opened, the air in the pipe first rushes out, followed by the water which is forced out by the pressure of the air in the tank.

Mr. Frank C. Wagner presented an elaborate paper on electric-light tests, giving an account of his work in testing the efficiency of two electric-light plants.

Prof. M. E. Cooley explained and illustrated a method of testing indicator-springs. The method consists in placing a small rigid rod in a vertical position, with its lower end resting upon a standard-scale. Upon the upper end of the rod, the under side of the piston of the indicator rests. The indicator is fastened to a horizontal bar movable on vertical guides. When this bar is pressed down by means of thumb-screws upon the guide-rods, the pressure on the piston, and, consequently, on the spring of the indicator, can be weighed upon the scales, and the position of the pencil recorded by a mark upon the card. Experiments made when the spring was heated nearly to 212°, showed that the resistance of a sixty-pound spring was diminished about one pound by change of temperature. Professor Cooley also explained a new smoke-burning device, consisting of a rectangular slot through each door of the furnace, just above the level of the hot coals, and two three-eighths of an inch steam-pipes entering the furnace above the doors, and so directed that a jet of steam passing through them strikes the fire about two feet back of the door. As the air passes in through the slots, and over the live coals, it becomes heated; and when it meets the steam-jets, is thoroughly mixed with the products of combustion, and completely oxidizes them. The only condition requiring careful attention is that live coals shall be kept at the front of the furnace, and nearly on a level with the slots in the doors.

In a paper entitled 'Deep water at Galveston, Tex., and how to secure it,' Dr. Alexander Hogg advocated the construction of a break-water extending out two miles from the shore as the best solution of the problem. From the discussion, it

appeared that the ocean-bed at that coast is a shifting quick-sand, and some doubt prevailed as to the practicability of such a structure at any reasonable cost.

Prof. R. H. Thurston's paper on cylinder condensation was of great scientific and practical value. The fact, the manner, and the effect of condensation in steam-cylinders, were made clear, even to those but little acquainted with the subject. Nearly all the losses met with in steam-engines are due to this cause. Watt found that three-fourths of the steam used in his engine was lost by condensation. In ordinary engines of modern construction, about twenty-five per cent is the usual loss; while in some large engines this loss has been reduced to ten or fifteen per cent. This waste depends upon the temperature of the surface of the cylinder when the steam enters, the temperature of this surface when the steam is exhausted, the extent of surface exposed, and the time of a revolution of the engine. These four variable elements bear different relations to each other in different engines operating under unlike conditions. The engineer has at present no means of designing an engine for given conditions for which he can calculate just what will be the waste, due to condensation from these causes. The complete solution of the problem requires that experiments be made, first, to ascertain the variation of loss due to a change of one of these quantities, all the others remaining constant, and that the law of such variation be mathematically expressed. A second of these variables is treated in the same manner; and so on until the law of variation of loss, due to change in each one of these variables, has been expressed. Then, if it be possible to combine all these results into a single formula, this formula will express the complete theory, and give the full solution of the problem. These experiments were made with a Harris-Corliss engine, capable of developing over five hundred horse-power. The engine was controlled by a large brake constructed for this purpose. Curves were plotted, representing the results of the different series of experiments recorded. While the full solution of the problem undertaken may involve the necessity of further experiments, the results tabulated in this paper will prove of great value to engineers. The paper will soon be in print.

A description of the large Prony-brake used in the experiments just referred to, formed the subject of a short paper by the same author. The size of this brake, and the extraordinary requirements made upon it, viz., that of transforming five-hundred horse-power of mechanical energy into heat, and giving up this heat with sufficient rapidity to prevent the undue heating of the machine, were the principal features of the device.

The discussion on the best methods of teaching mechanical engineering was opened by the report of a committee, through Prof. J. B. Webb its chairman, who alluded to the discussion of the same subject by the Society of mechanical engineers at Atlantic City. That discussion showed that engineers desire that technical schools shall give thorough preparation in theory and principles; and, also, that they insist upon the importance of such practical knowledge and skill — in all who are to direct men, and plan and execute work — as will enable the foreman or engineer to instruct, direct, and, if necessary, show his men how to do their work.

Prof. R. H. Thurston said that the training should be adapted to the work to be done. Therefore he favored classification into manual training-schools, schools of mechanic arts, and schools of engineering. A large proportion of the students who start at the beginning of the course will prove fitted to become workmen only, and may go from the manual training-school into a special course for some particular trade, or into the shop. Of the remainder, some will be able to do construction and simple designing, and might go from the school of mechanical arts into a special course preparing them for superintendents and directors of workmen. A few will have ability to become engineers; and should have, not only manual training and the mechanic arts, but, in addition, an unusually good knowledge of mathematics, applied mechanics, physics, including electricity, and some chemistry. Mechanical engineering requires a better knowledge of the physical sciences than any other profession. The higher a man goes, the better must be his knowledge of the use of tools. Teachers of engineering should be men who have had good training through a broad practical experience in the solution of engineering problems, and should have retained their theoretical knowledge by reading and study. Such men, at present, are rarely found.

Further discussion brought out the suggestions, that there are no manual training-schools where a boy can learn a trade before entering the higher schools; that the St. Louis and Chicago manual training-schools will not make workmen, and that probably not five per cent of their students will ever become workmen. These schools are appendices to the public schools, to give a general training by a different method. Technical schools try to crowd too much into four years. Principles should be taught upon which the man can build for himself. Men must know how to think, and they will be able to learn engineering. Practice is theory embodied; and, in so far as practical experience or work can aid theory, the two should be intimately mixed or blended from first to last. Manual training aids the judgment. Shop-work, interspersed with classical studies, would not diminish proficiency, and would add a valuable element. Shop-work at Michigan university is offered to all students, and is often elected by others than those studying engineering. Actual shop-work, too, is an efficient 'conceit killer.' More liberal preparation should be required for admission to technical schools. The important feature of the discussion was the advocacy of courses of study, leading one into the other, with natural stopping-places, each of which is a starting-point for some special trade, position or profession, adapted to the talent and ability of the individual student.